

**METHOD AND APPARATUS FOR IMPROVED PRINTING
WITH TONER HAVING MAGNETIC CONTENT**

- 5 (001) This application claims the benefit of United States Provisional Patent
Application serial number 60/453,868 filed March 11, 2003.

FIELD OF THE INVENTION

- (002) The present invention relates to electrographic development and/or printing
apparatuses which use toner having magnetic content to develop electrostatic images
10 carried on an insulating surface.

DESCRIPTION OF THE RELATED ART

- (003) The process of electrography involves forming an electrostatic charge image
on a dielectric surface, typically the surface of a photoconductive recording element
that is being drawn or otherwise conveyed through a developing station or toning
15 zone. The image is developed by bringing a two-component developer into contact
with the electrostatic image and/or the dielectric surface upon which the image is
disposed. The developer includes a mixture of pigmented resinous particles generally
referred to as toner and magnetically-attractable particles generally referred to as
carrier. The nonmagnetic toner particles impinge upon the carrier particles and
20 thereby acquire a triboelectric charge that is opposite the charge of the electrostatic
image. The developer and the electrostatic image are brought into contact with each
other in the toning zone, wherein the toner particles are stripped from the carrier
particles and attracted to the image by the relatively strong electrostatic force thereof.
Thus, the toner particles are deposited on the image. The magnetic carrier particles
25 are drawn to the toning shell by the rotating magnets therein. This magnetic force
generally does not affect the nonmagnetic toner particles.

- (004) However, within the toning zone the toner particles are affected by forces
other than the electrostatic force attracting the toner to the image and which may
degrade image quality. These forces include, for example, repulsion of toner from the
30 portion of the dielectric surface or photoconductive element that corresponds to the
background area of the image, electrical attraction of the toner particles to the carrier

particles, repulsion of toner particles from other toner particles, and electrical attraction to or repulsion from the toning shell depending on the polarity of the film voltage in the developer nip area. Methods of compensating for and/or balancing the effect of these other forces on the nonmagnetic toner particles to prevent any
5 significant adverse effect on image quality are well known in the art. However, the forces on toner particles having magnetic content are very different from the forces on nonmagnetic toner.

(005) In addition to the electrical forces acting on nonmagnetic toner as described above, toner having magnetic content is subjected to magnetic forces, such as, for
10 example, magnetic attraction of the toner particles to the carrier particles, to other toner particles, and to the rotating core magnet. All of these magnetic forces are generally in a direction away from the film or electrostatic image carrier. The only force acting to draw the toner onto the electrostatic image carried by the film or dielectric carrier is the electric force. Thus, the magnetic forces tend to counteract the
15 electric attraction of toner particles to the image. The strength of the electric force relative to the magnetic forces becomes stronger as the distance between the image and the core magnet increases. Therefore, the toner tends to be deposited on the trailing edge of the film or dielectric carrier. The result is an image having solids with heavy toning on the trailing edge of the image, and cross track lines (i.e., lines
20 perpendicular to the direction of travel of the dielectric support member or film) that are wider than the corresponding in track lines (i.e., lines that are parallel to the direction of travel of the dielectric support member or film).

(006) Therefore, what is needed in the art is a method and apparatus for balancing the magnetic forces within an electrographic development and/or printing machine
25 utilizing magnetic toner.

SUMMARY OF THE INVENTION

(007) The present invention provides a method and apparatus for balancing the magnetic forces within an electrographic development using magnetic toner.

(008) The invention comprises, in one form thereof, an electrographic development
30 machine including a dielectric film member for carrying an electrostatic image

thereon. A toner roller is disposed upon a first side of the dielectric film member. The toner roller has a core and an outer shell. The core includes a plurality of radially-disposed toner roller magnets, each of which has a respective north and south pole. The toner roller magnets are disposed such that adjacent pairs thereof have poles of
5 opposite polarity disposed proximate the shell. The toner roller provides the dielectric film member with a supply of developer material. The machine further includes means for balancing the magnetic forces acting on the magnetic toner particles.

(009) An advantage of the present invention is that the undesirable effects of magnetic forces upon the magnetic toner are substantially reduced.

10 **BRIEF DESCRIPTION OF THE DRAWINGS**

(010) The above-mentioned and other features and advantages of this invention, and the manner of attaining them, will become apparent and be better understood by reference to the following description of one embodiment of the invention in conjunction with the accompanying drawings, wherein:

15 (011) FIG. 1 is a side, elevation view, partially in cross-section, of a prior art toning or development station of an electrographic development machine;

(012) FIG. 2 illustrates the electrical and magnetic forces acting on an exemplary nonmagnetic toner particle and an exemplary carrier particle in the conventional electrographic development machine of Fig. 1;

20 (013) FIG. 3 illustrates the electrical and magnetic forces acting on an exemplary magnetic toner particle and an exemplary carrier particle in the conventional electrographic development machine of Fig. 1; and

(014) FIG. 4 is a side, cross-sectional view of one embodiment of an electrographic development machine of the present invention, and illustrates the electrical and
25 magnetic forces acting on an exemplary magnetic toner particle and an exemplary carrier particle therein.

(015) FIG. 5 a side, cross-sectional view of a second embodiment of an electrographic development machine of the present invention, and illustrates the

electrical and magnetic forces acting on an exemplary magnetic toner particle and an exemplary carrier particle therein; and

(016) FIG. 6 a side, cross-sectional view of a third embodiment of an electrographic development machine of the present invention, and illustrates the electrical and magnetic forces acting on an exemplary magnetic toner particle and an exemplary carrier particle therein.

(017) Corresponding reference characters indicate corresponding parts throughout the several views. The exemplifications set out herein illustrate one preferred embodiment of the invention, in one form, and such exemplifications are not to be construed as limiting the scope of the invention in any manner.

DETAILED DESCRIPTION OF THE DRAWINGS

(018) Referring now to the drawings and particularly to Fig. 1, there is shown a prior art toning or development station of an electrographic development or printing machine. Development station 10 is configured as a magnetic brush type, and includes housing 12 that defines reservoir 14 within which developer material D is disposed. The developer material D is, for example, a two-component small particle developer material having magnetic carrier particles of from approximately 20 to approximately 40 microns in diameter intermixed with nonmagnetic pigmented toner particles. Dielectric support member 16 is conveyed or moved in direction P past opening 18 in the upper portion of housing 12. The magnetic brush may operate according to the principles described in U.S. Pat. Nos. 4,473,029 and 4,546,060, the contents of which are fully incorporated by reference as if set forth herein. The carrier particles may (a) comprise a magnetic material exhibiting "hard" magnetic properties, as characterized by a coercivity of at least 300 gauss and (b) exhibit an induced magnetic moment of at least 20 EMU/gm when in an applied field of 1000 gauss.

(019) Toner roller 20 is disposed proximate opening 18. Generally, toner roller 20 applies toner to one or more latent images in the form of an electrostatic charge (neither of which are shown) formed on and carried by dielectric support member 16 as it moves or is conveyed in direction P past opening 18. Toner roller 20 includes a core 22 surrounded by a cylindrical shell 24. Core 22 includes a plurality of magnets

26 disposed around the outer surface thereof such that the poles at the outer portions of magnets 26 are arranged in alternating polarity as shown. Shell 24 is constructed of a nonmagnetic material, and may optionally have an axis (not referenced) that is offset from the axis (not referenced) of core 22 to thereby decrease the field strength of magnets 26 over the area of shell 24 that is furthest from magnets 26. Developer material D is less likely to adhere to shell 24 in the area of decreased magnetic field strength, i.e., the offset area, and is thus more likely to return to reservoir 14.

(020) In the embodiment shown, core 22 and magnets 26 are rotating clockwise, and shell 24 is rotating counterclockwise. However, it is to be understood that core 22 and shell 24 can be either fixed or rotatable, so long as developer material D is caused thereby to move in the field lines of magnets 26, through opening 18, and into contact with dielectric member 16.

(021) As support member 16 moves past opening 18, the latent image carried thereby in the form of an electrostatic charge attracts toner particles of developer material D from toner roller 20, through opening 18 and into adherence with the electrostatic charge on support member 16. The developed pattern is then typically transferred from support member 16 to a final substrate (not shown), such as, for example, a piece of paper.

(022) The electrical and magnetic forces acting on an exemplary nonmagnetic toner particle T_1 and an exemplary carrier particle C in conventional electrographic printing machine 10 are illustrated in Fig. 2. Carrier particle C is alternately attracted to and repulsed from toning roller 20 by magnetic force M_1 . The alternating nature or direction of force M_1 is due to the rotation of toning roller 20 and, thus, magnets 26. Nonmagnetic toner particle T_1 is attracted to carrier particle C by electrical force E_1 , which is the relatively weak electrostatic force that bonds toner particles to the carrier particles. Toner particle T_1 is attracted to support member 16 by force E_2 , i.e., the electrostatic image charge. When the electrical forces are properly balanced, force E_2 will be sufficiently stronger than force E_1 to cause toner particle T_1 to be stripped from carrier particle C and lodge onto a portion of the electrostatic image charged carried by support member 16. In part, the electrical forces are balanced by a development electrode layer (not shown), such as, for example, a layer of nickel, of

dielectric support member 16 that is held at ground potential. The nonmagnetic toner particle T_1 is not significantly affected by magnetic force M_1 .

(023) Referring now to Fig. 3, the electrical and magnetic forces acting within conventional electrographic printing machine 10 upon an exemplary toner particle having magnetic content T_2 and exemplary carrier particle C are illustrated. Magnetic force M_1 continues to act on carrier particle C to alternately attract and repulse carrier particle C to and from toning roller 20. Electrical force E_1 acts on magnetic toner particle T_2 in a substantially identical manner as it acted on nonmagnetic toner particle T_1 , i.e., tending to bond magnetic toner particle T_2 to carrier particle C. Electrical force E_2 also acts on magnetic toner particle T_2 in a substantially identical manner as it acted on nonmagnetic toner particle T_1 , i.e., magnetic toner particle T_2 is attracted by force E_2 to the electrostatic image charge carried by support member 16. Magnetic toner particle T_2 is, however, subjected to magnetic forces that did not significantly affect nonmagnetic toner particle T_1 .

(024) Magnetic toner particle T_2 is acted upon by magnetic forces M_2 , M_3 , and M_4 . More particularly, magnetic force M_2 exists between toner particle T_2 and carrier particle C, and tends to draw toner particle T_2 toward carrier particle C. Magnetic force M_3 exists between toner particle T_2 and toning roller 20, and tends to draw toner particle T_2 toward toning roller 20. Magnetic force M_4 exists between toner particle T_2 and a second magnetic toner particle T_3 , and tends to draw toner particle T_2 toward toner particle T_3 . None of magnetic forces M_2 , M_3 , and M_4 are directed toward dielectric support member or film 16. Rather, magnetic force M_3 is generally directed away from dielectric support member or film 16, and magnetic forces M_2 and M_4 are generally directed parallel to dielectric support member or film 16 and in opposing directions. Thus, magnetic forces M_2 , M_3 and M_4 tend to counteract or reduce the effective electrical force E_2 that attracts magnetic toner particle T_2 to the electrostatic image charge carried by support member 16, and thereby degrade overall image quality.

(025) Image quality is also degraded due to scavenging of toner particles from the electrostatic image carried on support member 16. This scavenging process occurs when a toner particle that has already been deposited on support member 16 is

subsequently pulled back off the support member 16 by a subsequent carrier particle that is in close proximity to the toner particle. Scavenging is primarily responsible for the variation in the amount of toner deposited from the leading edge to the trailing edge of an image. Only as the image carried by support member 16 emerges from the developer nip area is the toner deposition relatively unaffected by the scavenging process, and thus heavier cross track lines and heavy trailing edges on other image shapes result.

(026) Referring now to Fig. 4, one embodiment of an electrographic development or printing machine 30 in accordance with the present invention is shown, and the electrical and magnetic forces acting within electrographic development machine 30 upon an exemplary toner particle having magnetic content T_2 and exemplary carrier particle C are illustrated.

(027) Electrographic development machine 30 includes, in addition to toning roller 20 and dielectric support member or film 16, a magnetic keeper 34. Magnetic keeper 34, such as, for example, a wire or plate, disposed such that film or dielectric support member 16 is between keeper 34 and toner roller 20. Magnetic keeper 34 is constructed of a range of materials of varying ferromagnetic strength, such as, for example, a thin wire of slightly magnetic stainless steel having a relatively small amount of ferromagnetic material, such as, for example, 0.04 grams per centimeter of length, for very small ferromagnetic strength/effect to a cold rolled steel plate having a relatively large amount of ferromagnetic material, such as, for example, 16 grams per centimeter of length, for very strong ferromagnetic strength/effect. The amount of ferromagnetism and location of magnetic keeper 34 is dependent at least in part upon the desired effect on the toner deposition process. The relatively low magnetic reluctance of magnetic keeper 34 tends to draw or attract magnetic toner particle T_2 , thereby counteracting the magnetic forces M_2 , M_3 and M_4 which, as described above, tend to counteract or reduce the effective electrical force E_2 attracting magnetic toner particle T_2 to the electrostatic image charge carried by support member 16.

(028) In electrographic development machine 30, as shown in Fig. 4, magnetic forces M_2 , M_3 , and M_4 act on magnetic toner particle T_2 in a substantially identical manner as described above in regard to electrographic development machine 10, i.e.,

magnetic forces M_2 , M_3 , and M_4 remain directed generally away from dielectric support member 16 and tend to degrade image quality. However, an additional magnetic force M_5 acts on magnetic toner particle T_2 . More particularly, magnetic force M_5 exists between magnetic toner particle T_2 and magnetic keeper 34, and tends to draw magnetic toner particle T_2 toward keeper 34. Since keeper 34 is disposed between magnetic toner particle T_2 and dielectric support member 16, magnetic force M_5 is directed toward and tends to draw magnetic toner particle T_2 to dielectric support member 16. Thus, magnetic force M_5 is directed generally opposite to magnetic force M_3 and thereby counteracts or generally balances the magnetic forces acting on magnetic toner particle T_2 within development machine 30. With the magnetic forces generally balanced, the electrical forces acting on toner particle T_2 predominate and the above-described undesirable effects of the magnetic forces on the image are substantially reduced.

(029) Referring now to Fig. 5, a second embodiment of an electrographic development or printing machine 60 in accordance with the present invention is shown, and the electrical and magnetic forces acting within electrographic machine 60 upon an exemplary toner particle having magnetic content T_2 and exemplary carrier particle C are illustrated. Whereas magnetic keeper 34 acts to straighten or balance magnetic field lines in a passive manner, the following embodiments of printing machines employ active structures to straighten/balance the magnetic field lines.

(030) Electrographic development machine 60 includes, in addition to toning roller 20 and dielectric support member or film 16, a rotating magnetic 64. Rotating magnet 64 is disposed generally opposite toner roller 20, and with dielectric support member 16 disposed between rotating magnet 64 and toner roller 20. Rotating magnet 64 includes a plurality of magnets 66 arranged such that the poles thereof are opposite to the poles of magnets 26 of toner roller 20. Thus, the magnetic forces M_3 and M_5 are directed generally opposite to each other and approximately equal in magnitude. The magnetic forces acting on magnetic toner particle T_2 within electrographic development or printing machine 60 are therefore generally balanced, and the electrical forces predominate thereby substantially reducing the above-described undesirable effects of the magnetic forces on the image.

(031) The phase angle between the rotating north and south poles can be adjusted to tune the magnetic field between the two core magnets 22 and 64. For example, a north pole on one core may be in phase with a north pole on the other such that their fields precisely cancel out. Having the poles exactly out of phase, with a north pole facing a south pole results in a strong field which varies from one direction to the other between the two core magnets. The phase angle between the rotating core magnets determines the effect on a magnetic toner particle. This phase angle can thus be adjusted to either strengthen the image lead or trail edge or to balance the toner deposit on the dielectric support member 16, thereby modifying the appearance of the toned image as desired.

(032) Since the cores 22 and 64 can be computer controlled, field strength as well as direction can be programmed to improve image edge balance as well as helping to keep the background or interframe areas clean.

(033) In the embodiments shown, a magnetic keeper 34 and a rotating magnet 64 are utilized as means for counteracting and generally balancing the magnetic forces acting on the magnetic toner particles within electrographic development machines 30 and 60, respectively. However, it is to be understood that the present invention can be alternately configured with various other means for balancing the magnetic forces within the electrographic development machines. Such means include various magnetic and/or electromagnetic structures, such as, for example, a wire coil electromagnet.

(034) As shown in Fig. 6, electrographic development machine 90 utilizes a wire coil electromagnet 94 as the magnetic/electromagnetic structure to balance the magnetic forces within the development machine. Machine 90 also includes controller 100, such as, for example, a microprocessor that actively controls and drives electromagnet 94 to thereby manipulate the magnetic field characteristics on a real-time basis. Thus, machine 90 is able to reduce the effects of developer pickup and/or carrier pickup on image quality. Since the electromagnet 94 can be computer controlled, its level of the strength as well as its direction can be programmed to improve image edge balance as well as helping to keep the background or interframe areas clean.

(035) It should be particularly noted that the magnetic or electromagnetic structure for balancing the magnetic forces within the development machine can range from the relative simplicity of the magnetic keeper 34 of electrographic machine 30 to the moderately complex rotating magnet 64 of machine 60 and beyond to structures that
5 are substantially more complex and/or more powerful. These structures may be implemented to alter the magnetic field generated by the core 22 in the development zone, as has been described herein. The complexity or power required of the magnetic force balancing structure or means depends, at least in part, upon the configuration of particular development machine upon which the balancing structure
10 is to be used including, such as, for example, the diameter or size of the toning roller, the number of magnets therein, and the magnetic forces in the nip area.

(036) While this invention has been described as having a preferred design, the present invention can be further modified within the spirit and scope of this disclosure. This application is therefore intended to cover any variations, uses, or
15 adaptations of the present invention using the general principles disclosed herein. Further, this application is intended to cover such departures from the present disclosure as come within the known or customary practice in the art to which this invention pertains and which fall within the limits of the appended claims.